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Performance and Reliability Modeling of MEMS: Modeling the Effects of Mechanics and Chemistry on Material Damage and Failure

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Project Description

Factors will be studied in this project that affect the performance of microElectroMechanical Systems (MEMS) from two perspectives:

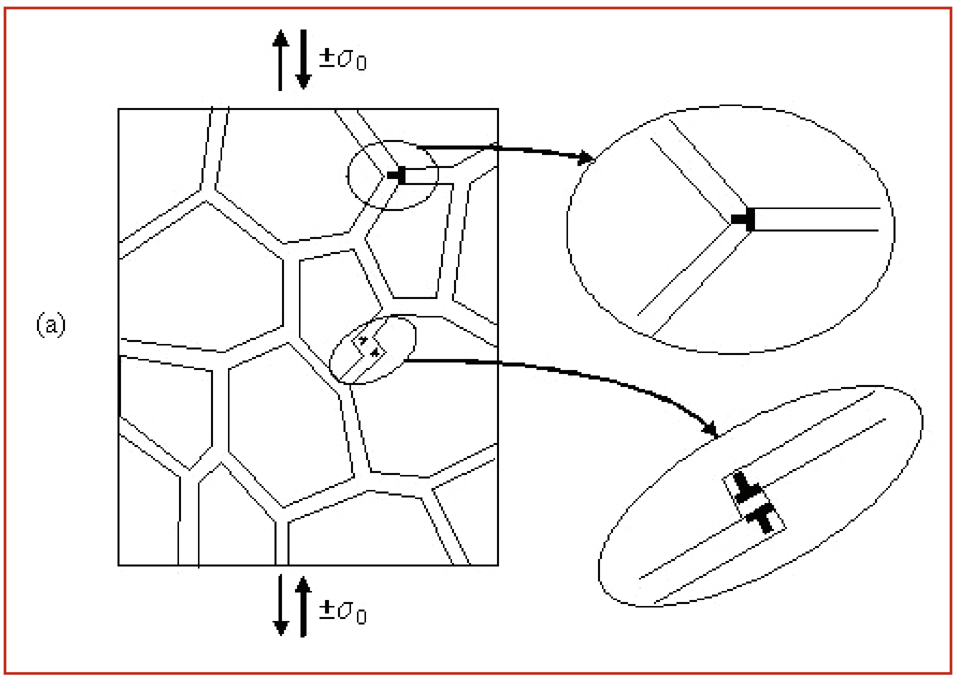
- Creep and recrystallization in relatively low-cycle, thermally activated devices
- Fatigue in high-cycle devices

Four tasks will be performed at the discretion of the Sandia principal investigator:

- Construct nonlinear model with drastically changing lattice structure under temperature and stress field; model crack interaction localized phase transforming area; produce theoretical model of mechanisms for nucleation and growth of fatigue cracks in polysilicon materials; molecular dynamics modeling of low-cycle high-amplitude loading of a monocrystal material with defects.
- Derive nonlinear equations of catastrophic deformations and fatigue crack growth; model grain growth in polysilicon materials under thermal treatment and creep.
- Model couple interaction between crack growth, stress-assisted diffusion, and chemical reactions.
- FEM and molecular numerical simulation of damage evolution in polycrystalline solids.

Technical Purpose and Benefits

Microsystems fail not only by catastrophic modes, in which devices sustain severe damage, but also by more subtle modes that result in a loss of functionality, though the devices remain largely intact. The catastrophic modes tend to involve a complete breakdown in any



Nucleation of nanoscale cracks/nanovoids in polysilicon under fatigue load.

one of the thermal, mechanical, or electrical properties of the device, such as the fracture of a structural member. The more subtle failure modes tend to involve a coupling of electron-thermomechanical responses such as a creep leading to a change in electrical resistivity and thermal conductivity causing the force or range of motion in an actuator to fall outside design tolerances. Accurate life predictions require material property evolution to be included in coupled-physics device simulation in order to assess how all these factors affect device performance over time. This contract studies factors affecting the performance and reliability of MEMS from two perspectives: (1) creep and recrystallization in relatively low-cycle, thermally activated devices and (2) fatigue in high-cycle devices.

The results of this project will improve our understanding of the performance and reliability characteristics of MEMS so as to allow the adaptation of this cutting edge technology in the stockpile.

Meeting in St. Petersburg—From left to right: Dr. John Aidun, Academician Nikita Morozov, and Dr. Tony Chen.

Collaboration between Sandia National Laboratories (SNL), Livermore, CA, USA, and IPME (Research Institute of Mechanical Engineering Problems), St. Petersburg, Russia

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